WHITE PAPER NO. 18 – EVALUATION OF AN ALTERNATIVE APPROACH OF CALCULATING MASS, SEDIMENT VOLUME, AND SURFACE CONCENTRATIONS IN OPERABLE UNIT 5, GREEN BAY

Response to Comments on the

REMEDIAL INVESTIGATION FOR THE LOWER FOX RIVER AND GREEN BAY, WISCONSIN, FEASIBILITY STUDY FOR THE LOWER FOX RIVER AND GREEN BAY, WISCONSIN PROPOSED REMEDIAL ACTION PLAN FOR THE LOWER FOX RIVER AND GREEN BAY, AND RECORD OF DECISION FOR OPERABLE UNIT 1 AND OPERABLE UNIT 2

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ABSTRACT

The paper was developed to addresses concerns raised during the public comment period for the *Final Remedial Investigation for the Lower Fox River and Green Bay, Wisconsin* (RI) (RETEC, 2002a), the *Final Feasibility Study for the Lower Fox River and Green Bay, Wisconsin* (FS) (RETEC, 2002b), and the *Proposed Remedial Action Plan, Lower Fox River and Green Bay* (Proposed Plan) (WDNR and EPA, 2001), on the differences in polychlorinated biphenyl (PCB) mass and contaminated sediment volume on Green Bay. Specifically, concerns were raised concerning estimates previously made by the University of Wisconsin and those presented by the Wisconsin Department of Natural Resources (WDNR) in Technical Memorandum 2f (TM 2f). These two approaches to estimating Bay properties were evaluated and compared and an alternative to both approaches was developed. This alternative method was then used to estimate PCB mass and contaminated sediment volume in Green Bay using data received during the public comment period.

1 INTRODUCTION AND BACKGROUND

The purpose of this paper is to present the results of an alternative analysis of the PCB mass and volume estimates originally presented in TM 2f *Estimates of Sediment Bed Properties for Green Bay* (WDNR, 2000). This work was undertaken in response to comments received on the RI (RETEC, 2002a), the FS (RETEC, 2002b) and Proposed Plan (WDNR and EPA, 2001), in which TM 2f PCB mass and volume estimates were presented. TM 2f is included as part of Appendix A to the *Final Model Documentation Report for the Lower Fox River and Green Bay, Wisconsin* (MDR) (WDNR and RETEC, 2002).

Numerous investigations of Green Bay sediments provide information about sediment bed properties at discrete points in space (and time). However, no investigation can provide information about sediment properties through the entire spatial and volumetric extent of the sediment bed without additional analysis. The results of these studies must be interpolated in a consistent and technically sound manner to provide a continuous representation of sediment bed properties. TM 2f, developed collaboratively between the state and the Fox River Group (FRG) (LTI, 1999), presented a methodology to estimate sediment bed properties from the results of field investigations and applied those methodologies to Green Bay. A specific intent of TM 2f was to provide a single, consistent set of interpolated sediment bed properties for use in model evaluation and Superfund (CERCLA) RI/FS and Risk Assessment (RA) efforts.

TM 2f developed a method to evaluate sediment conditions across the whole of Green Bay, based on data collected at specific points. These properties could then be used to evaluate risks to human health and the environment based on PCB distribution in sediments, as well as provide a means for estimating the mass and volume of PCB-contaminated sediments in the Bay.

This white paper is necessary to respond to comments from the academic and regulated communities as well as other groups regarding the analytical procedures and assumptions of physical factors used in TM 2f. These comments expressed concerns covering areas such as:

- Overestimates PCB mass and contaminated sediment volume in Green Bay
- The analytical procedures and assumptions of physical factors used in the creation of TM 2f
- That incorrect data used in the initial TM 2f analysis including depth of contamination and the areal extent of the coverage

This white paper evaluates these different factors on the estimation of concentration distribution, mass, and volume of PCBs in Green Bay.

2 COMPARISON OF TECHNIQUES USED TO ESTIMATE GREEN BAY PCB MASS AND VOLUME

Estimates of PCB mass, PCB concentration, as well as PCB-contaminated sediment volume properties of Green Bay were developed by WDNR staff. Using methods developed by Limnotech, Inc. (LTI) on behalf of the FRG (LTI, 1999), the results of this work is presented in TM 2f. TM 2f presents a methodology to estimate sediment bed properties, and applies this methodology to devise estimates of PCB mass, PCB concentrations within sediments, and PCB-contaminated sediment volumes for Green Bay. As TM 2f readily identifies, there are numerous approaches to estimating sediment bed properties. During the development of Technical Memorandum 2e (TM 2e), *Estimation of Lower Fox River Sediment Bed Properties* (WDNR, 1999), WDNR technical staff tested several different surface weighting and data interpolation techniques to determine the most appropriate method for estimating sediment bed properties for the Lower Fox River. These same techniques were subsequently used in the generation of TM 2f.

Another estimate of PCB mass and sediment bed properties, developed by researchers at the University of Wisconsin-Madison Environmental Chemistry and Technology Program and the University of Wisconsin-Milwaukee Water Institute (UW) for the purpose of the Green Bay Mass Balance Study (GBMBS) was presented by Manchester et al. (Manchester-Neesvig et al., 1996) and was the focus of comments.

The basic mechanics of these two approaches (TM 2f and UW) are reviewed in the following subsections. Differences between the methodologies and the variables that may contribute to the different estimates of PCB mass are also identified.

2.1 UW'S METHODS OF PCB MASS AND CONTAMINATED SEDIMENT VOLUME ESTIMATION IN GREEN BAY

The approach used by the UW was developed on prior sediment sampling experience in Green Bay. Based on their experience, the UW used a 25-square-kilometer (km^2) grid (5-kilometer [km] by 5-km cells) to establish a regular pattern of sample locations across the entire Bay. The 25-km^2 grid was augmented by a 1-km^2 grid at station 26. Sediment samples were taken at the center of each grid cell and used to define the existence and location of historic sediments based on the presence or absence of organic carbon in the samples. A total of 64 sample locations was identified as having historic sediments. Because PCBs have been shown to be associated with sediments having high organic carbon content, core samples were taken at each of these 64 grid cells (Figure 1). Sediment cores were segmented into 1-centimeter (cm), 2-cm, and 5-cm thickness layers. These samples were then analyzed for a number of physical and chemical constituents, including total mass, porosity, volume, PCB-homologue, cesium-137, and lead-210. The bulk density of each sample was measured, and used in conjunction with the PCB concentration measurements to calculate depth-weighted PCB mass-per-unit-volume estimates for each core location. This value was then extrapolated or "scaled" to the 25-km^2 area of the representative cell to estimate PCB mass within each of the 64 cells. By

summing all cells, the UW generated a Green Bay mass estimate totaling 8,483 kilograms (kg) of PCBs.

2.2 WDNR METHODS OF PCB MASS ESTIMATION IN GREEN BAY USED IN TM 2F

A number of Geographic Information System (GIS)-based interpolation frameworks were evaluated as part of TM 2e for the Lower Fox River. From this evaluation, it was determined that a raster-based interpolation framework (i.e., a regular grid network) is better suited for estimating sediment bed properties than a vector-based (irregular polygon network) approach. For consistency, these same raster methods were selected for use in the development of TM 2f.

Using ArcView 3.1 with Spatial Analyst 1.1 as the selected GIS, the raster-based Inverse Distance Weighting (IDW) interpolation algorithm was used to interpolate Green Bay sediment bed properties. Through IDW interpolation, values for an unsampled location are estimated as an average of known sample values within its vicinity. Because this technique uses a distance-dependent weighting factor, the influence of surrounding known values decreases with distance from the location being estimated.

As part of TM 2f development, a literature search was conducted and the results used to construct a data set of physical and chemical sediment data parameters for Green Bay spanning a period from 1968 to 1998. The data source components of this data set, which include the sediment data developed by the UW for the GBMBS, are stored in the Fox River Environmental Database (www.tecinfodex.com/frdb/).

Because sediment sample segmentation schemes varied from data source to data source, it was necessary to assimilate all PCB concentration and bulk density into a consistent sediment-layering scheme accomplished by use of a thickness-weighted-averaging computer program. This layering scheme was based on the prescribed sediment layers used as input in the sediment toxicity transport model GBTOX.

FIGURE 1 UW/GBMBS SAMPLE LOCATIONS AND 25-KM^2 CELL COVERAGE

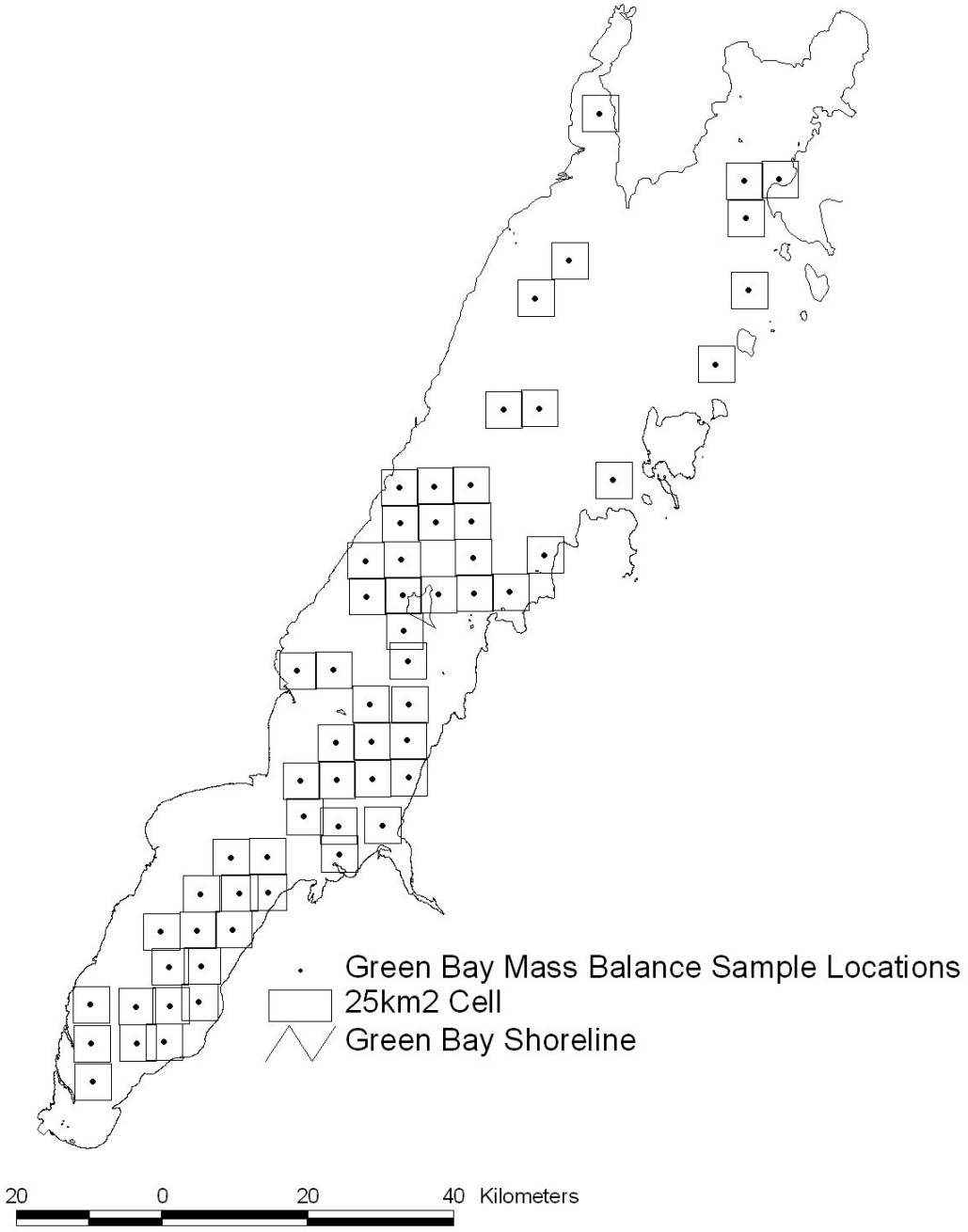


TABLE 1 SEDIMENT LAYER INPUT STRUCTURE FOR TM 2F

TM 2f Layer Structure	Sediment Depth (cm)
1	0–2
2	2–4
3	4–6
4	6–10
5	>10

IDW-based GIS interpolations of sediment PCB concentration and bulk density were generated using an 8,000-meter radius of influence and a polynomial power function of 2, over a 100-meter by 100-meter grid division of the Bay. As discussed in TM 2f, these IDW parameters were determined to generate estimates that minimized root-mean-square errors. For each of the five sediment layers, a resulting 100-meter by 100-meter gridded GIS "coverage" was generated for each parameter. The PCB concentration coverage was then multiplied with the associated bulk density coverage to produce a PCB mass-per-unit-volume coverage for each sediment layer. Each of these coverages was then multiplied with a coverage of interpolated sediment thickness (depth of analysis) to produce a final coverage for each sediment layer displaying PCB mass estimates for each 100-meter by 100-meter grid cell. These cells were then summarized across a bounding GIS coverage (area of analysis) depicting the occurrence of soft sediment in the Bay, resulting in an estimated total of 69,955 kg of PCBs in Green Bay. For more information, please review TM 2f in its entirety.

2.3 DIFFERENCES IN METHODS

There are differences between the two approaches described above. While the physical and chemical parameters used for estimating PCB mass and sediment volume are the same for both approaches, the differences in PCB mass and contaminated sediment volume estimates may be attributable to:

1. The interpolation method applied to these parameters. WDNR's use of IDW assumes an exponential trend of sediment parameter values throughout an 8-km radius from an interpolated sample point, whereas UW's approach assumes a linear representation of sediment parameter values throughout an entire 25-km^2 cell.

2. The parameter values themselves, which includes differences in the data sets used in the interpolations, the horizontal and vertical areas over which the interpolations are applied, and the estimates of contaminant depth.

3 EVALUATION OF METHODS

In order to determine if differences in PCB mass and contaminated sediment volume estimates are attributable to the differences between these two interpolation methods, WDNR devised a test to directly compare the results of the TM 2f method with those of the UW. This evaluation involved comparing the TM 2f and UW methods by using the same data, over the same area and the same sediment thickness. Prior to conducting this evaluation, it was first necessary to define any differences in the other PCB mass calculation parameters and refine these values so that they were consistent between the two methods. Included in Appendix A of this white paper is a data directory (CD:\GreenBay\alternative_analysis\) that provides details on this test.

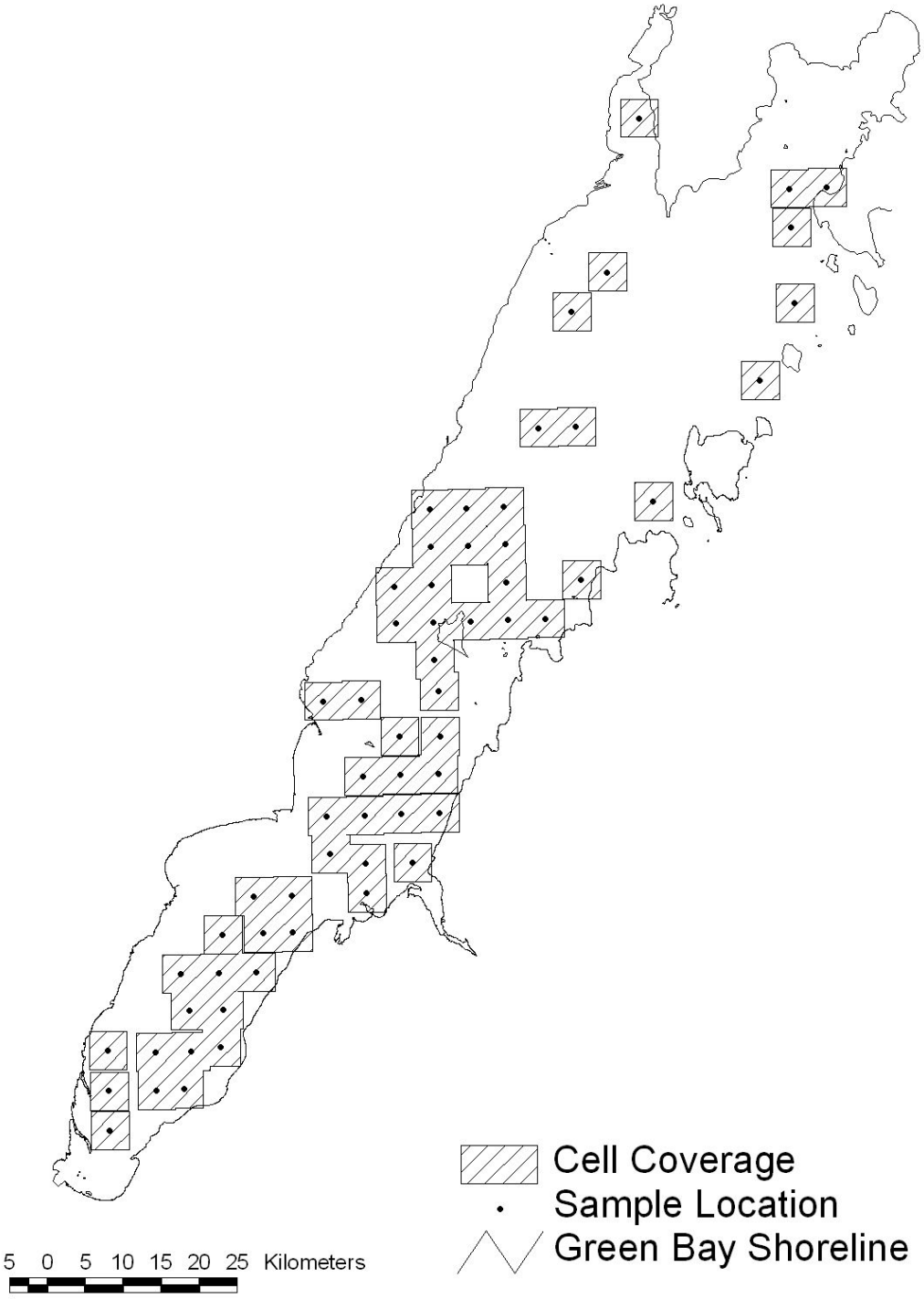
3.1 PARAMETERS CONSIDERED IN COMPARATIVE EVALUATION

Sediment Data: The data set used in this evaluation was the same data set used by UW. This included locational, bulk density, PCB concentration, and segmentation information for each of the 64 sediment core samples (Appendix A, data CD).

Spatial Extent/Area of Analysis: The spatial extent of the Green Bay sediment bed used in this evaluation was identical to that used by UW. To do this, WDNR created a GIS coverage of the outline of the 25-km^2 GBMBS cells (Figure 2). This coverage was then used as an interpolation barrier that limited the spatial extent of the IDW calculations.

Sediment Thickness/Depth of Analysis: For purposes of this method comparison, the evaluation test was conducted using sediment information for the top 1 cm (0 to 1 cm data) only.

FIGURE 2 GBMBS 25-KM^2 CELL OUTLINE; AREA OF ANALYSIS USED FOR METHOD TEST



3.2 RESULTS

The interpolation method evaluation test produced an initial map coverage of PCB mass estimates for the top (0 to 1 cm) layer of sediment in Green Bay (Figure 3) as well as a quantitative summary of total PCB mass (Table 2). When compared to the mapped mass results generated by the UW, the WDNR map displays a "saddle" of high PCB mass in an area located between relatively low PCB concentration and high bulk density measurements. This phenomena is an artifact of the IDW interpolation. Further analysis confirmed that, by multiplying together interpolated values of PCB mass and bulk density, the IDW approach could result in PCB mass estimates between cores that are higher than the bounding known PCB mass values. Figure 3 displays a "saddle" artifact in the southern portion of the Bay. Quantitatively, this artifact accounts for a 14 percent difference (increase) in PCB mass compared to that put forth by the UW (Table 2).

Based on these results, an additional GIS interpolation was conducted to directly compare the differences between the assumptions of the relationship between sediment PCB mass and bulk density. For this comparison, IDW interpolations were conducted on PCB mass values calculated for each sediment sample location. This interpolation produced an additional map coverage (Figure 4) showing a clear absence of the artifact saddle. The PCB mass summary defined by this coverage shows that these estimates, computed by use of a GIS-based IDW algorithm, are the same as that produced by the UW in their linear-scaled approach to estimating Green Bay PCB mass (Table 2).

TABLE 2 RESULTS OF IDW-INTERPOLATED PCB MASS, GBMBS DATA (0 TO 1 CM)

Method	PCB Mass		PCB Mass	
	Sum of GBMBS 25-km^2 Cells (kg)	Sum of GBMBS 25-km^2 Cells (% difference)	Alternative Analysis GBMBS Cell Outline "Area of Analysis" (kg)	Alternative Analysis GBMBS Cell Outline "Area of Analysis" (% difference)
UW/GBMBS	585	0	Not Applicable	Not Applicable
WDNR TM 2f IDW Method [1]	676	+14	627	+7
WDNR Evaluation IDW Method [2]	590	+0.81	544	-7

Notes:

[1] Bulk density and PCB concentration were interpolated independently, and the resulting grid coverages multiplied together to compute PCB mass.

[2] Bulk density and PCB concentration were first multiplied to compute PCB mass at each sample location, then these mass values were interpolated to result in a grid coverage of PCB mass.

Table 2 is a summary of both of WDNR's IDW interpolation results compared to UW's results. Note that, when summarized over the same area as the UW study ("Sum of GBMBS 25-km^2 cells"), WDNR's mass-interpolated evaluation results differ from UW's by less than 1 percent. The IDW approach used in TM 2f, in which sediment bulk density and PCB concentration are interpolated as independent variables, causes

interpolation artifacts which result in PCB mass estimates 14 percent higher than UW's estimates.

In considering the area-of-analysis polygon created from an outline of the UW's GBMBS cells, WDNR's PCB mass summaries differ by 7 percent.

The results of the method evaluation test show that differences in UW's mass estimate and the mass estimate and contaminated sediment volume presented in TM 2f can not be attributed to the IDW interpolation algorithm.

FIGURE 3 RESULTS OF METHOD TEST; PCB MASS (0 TO 1 CM) AS A RESULT OF SEDIMENT BULK DENSITY AND PCB CONCENTRATION INTERPOLATED SEPARATELY

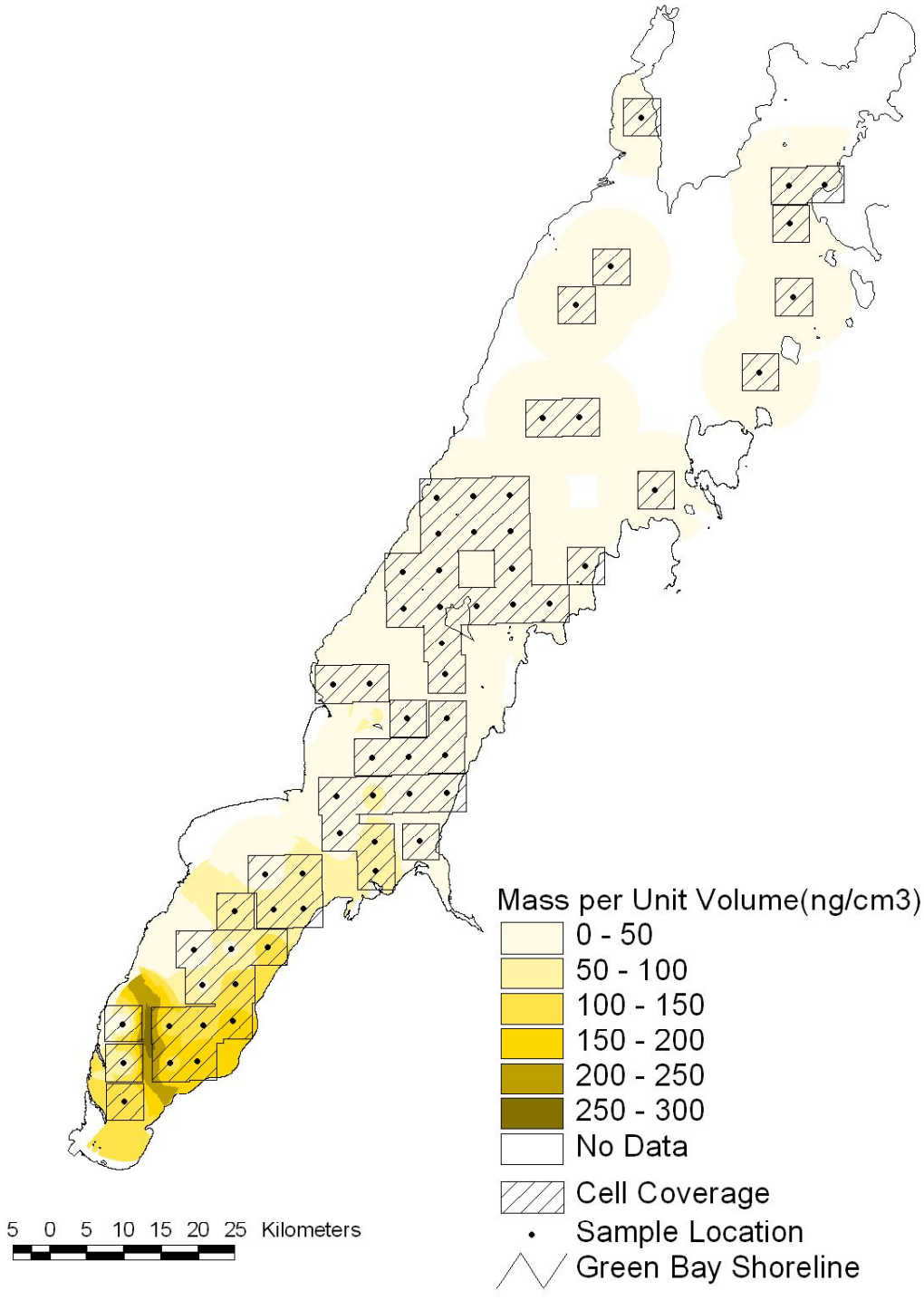
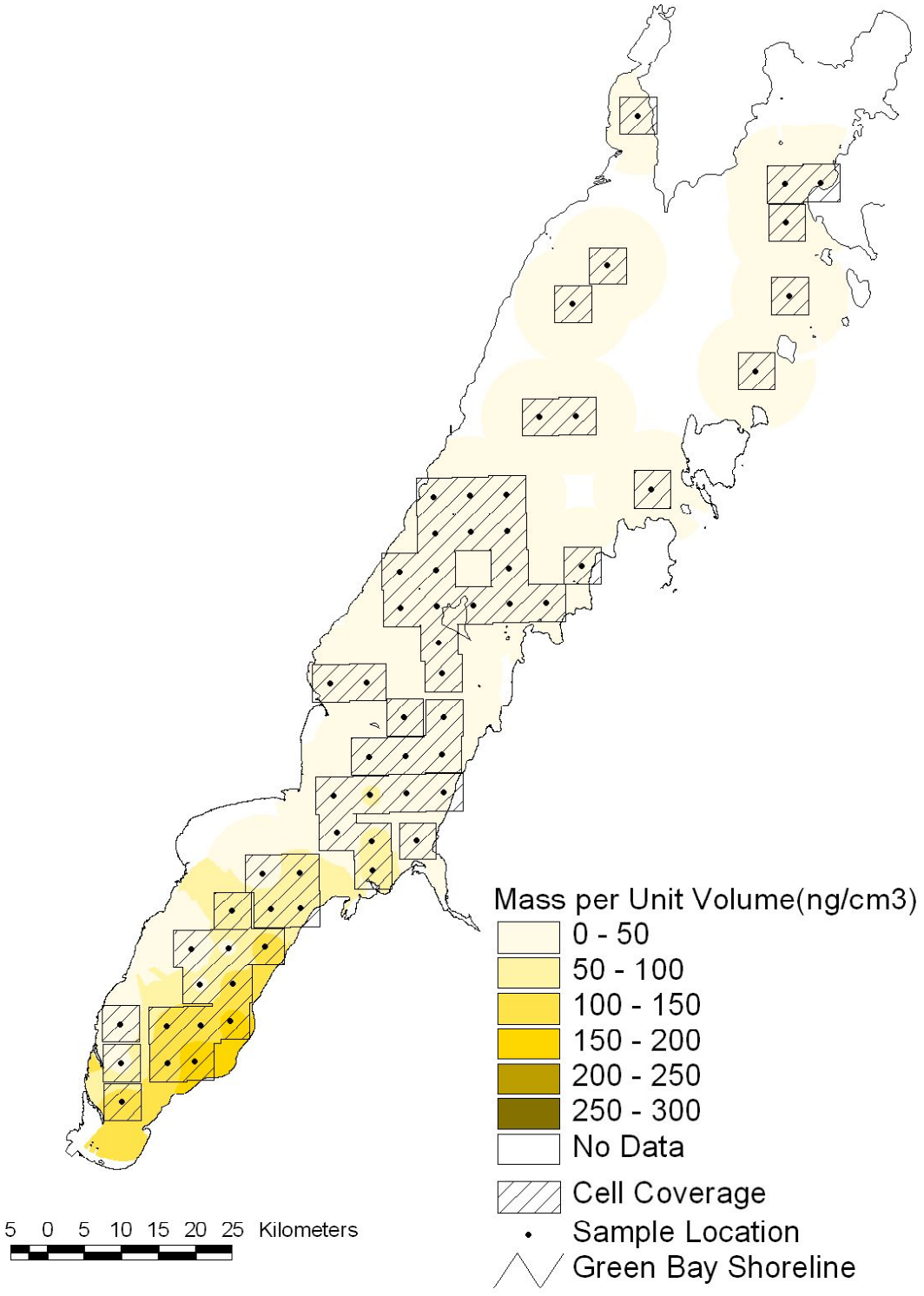


FIGURE 4 RESULTS OF METHOD TEST; PCB MASS (0 TO 1 CM) AS A RESULT OF PCB MASS INTERPOLATED



4 COMPARISON OF INPUT DATA

As a result of the analysis done in Section 3, it was necessary to consider the influence of other parameters on the interpolation results. This parameter evaluation identified the need to have a consistent method for GIS-based techniques to estimate PCB mass and contaminated sediment volume in Green Bay. WDNR developed this alternative method for estimating PCB mass and contaminated sediment volume following the consideration of these parameters. This alternative method is based on the TM 2f IDW approach while identifying specific criteria data must meet to be used. This alternative method also identifies a larger area for the interpolation than was included in the initial UW effort. Included in Appendix A of this white paper is a data directory (CD:\GreenBay\methodtest\) that provides details on this work.

4.1 INTERPOLATION DIFFERENCES

Generally speaking, the differences in mass estimates can be explained by differences in the values assigned to sediment parameters, and the way in which these parameters are combined in the IDW interpolation. Results of the method evaluation test show that, by interpolating separately across PCB concentration and bulk density values, isolated areas of high-PCB mass may be predicted to exist between areas of known low PCB concentration and high bulk density. This interpolation artifact has the potential to cause over-estimates of PCB mass throughout Green Bay. Table 2 shows that this phenomena can lead to mass estimates ranging between 0.8 and 14 percent. The following is a discussion of significant influences brought about by the other mass-estimate variables.

4.1.1 Data Used

More validated data from the Fox River Database was used in the original TM 2f than by the UW. This is primarily due to the fact that the UW method only used data from the GBMBS taken at the center of the 25-km^2 grids while TM 2f made use of a larger data set of validated information for all of Green Bay. The GBMBS data from the center of the 25-km^2 grid is referred to as "at core" samples and represent data points with both PCB concentration and bulk density from the same sample location. These are referred to as "matched pair" data. This matched pair data is not available at all sample locations, thus limiting the size of the database used.

Once it was determined that generally the TM 2f approach was different, but fundamentally equivalent to the UW method for estimating mass, the next step was to evaluate the impact of newer data on the interpolations. To be consistent, it was decided to carry out GIS interpolations on calculated "at core" PCB sample locations. The use of sediment sample data was therefore restricted to information containing PCB concentration values paired with bulk density values from the same sample segment. These restrictions limited the original PCB concentration and bulk density data used in TM 2f to a select number of data sets containing paired data of concentration and bulk density values. The data sets used in this alternative method are: 1989 GBMBS, 1995 WDNR, 1998 BBL, and 2001 BBL (Figure 5 and Appendix A). These data are all identified in the Data Management Report (Appendix A to the RI) (RETEC, 2002a).

A review of the 1995 WDNR data set resulted in the elimination of one sample point (DNR95-106) because it was found to be located within the confines of the regularly dredged federal navigation channel. The 2001 BBL data set was made available for this analysis through comments received on the Proposed Plan.

4.1.2 Area of Analysis

The PCB mass estimates generated by UW covered an area of Green Bay of 1,600 square km and did not include the Bay south of Long Tail Point. For TM 2f, the GIS area-of-analysis coverage covered 1,800 square km, and did include the southern Bay. The IDW approach used in this analysis is consistent with TM 2f, as is discussed in Section 2.2.

Upon review of the coverage area, it was noted that not all of the GBMBS data points were in a representative area in TM 2f. For this alternative method, the area of analysis was adjusted by creating 5-km by 5-km grid cells around those GBMBS points in the north Bay not originally located in the TM 2f area-of-analysis coverage (Figure 6). Note that this cell size is the same as UW's representative cell size.

As mentioned above, the UW did not include Green Bay south of Long Tail Point in its analysis. This area was included in TM 2f. However, for the work conducted in TM 2f, the southern Bay was data-sparse, and therefore, application of the IDW method resulted in large areas of this region being influenced by a select few sediment data points near the Bay head. As part of the comments received on the Proposed Plan, the FRG submitted data collected in 2001 by the consulting firm of Blasland, Bouck and Lee (BBL) for the southern bay south of Long Tail Point. The inclusion of the 2001 BBL data set in this alternative approach resulted in a refinement of the southern Bay area of analysis.

A separate GIS coverage of the southern Bay (south of Long Tail Point) was created and populated with the 1995 WDNR and 1998 BBL sediment data used in TM 2f, as well as the 2001 BBL sediment data set (Figure 6). Following the same logic that was used to determine the IDW radius of influence in the north Bay, a radius of 4,000 meters was used in this alternative approach for interpolations in the south Bay because it maximized the inter-point spatial coverage. From this work, it was determined that an IDW power function of 4 would yield accurate PCB mass estimates while minimizing interpolation error.

For the alternative method, the PCB mass and contaminated sediment volume for the northern area and southern area were calculated separately and then combined to provide an overall mass and volume estimate for the entire Bay.

FIGURE 5 TM 2F ALTERNATIVE APPROACH: DATA SOURCES

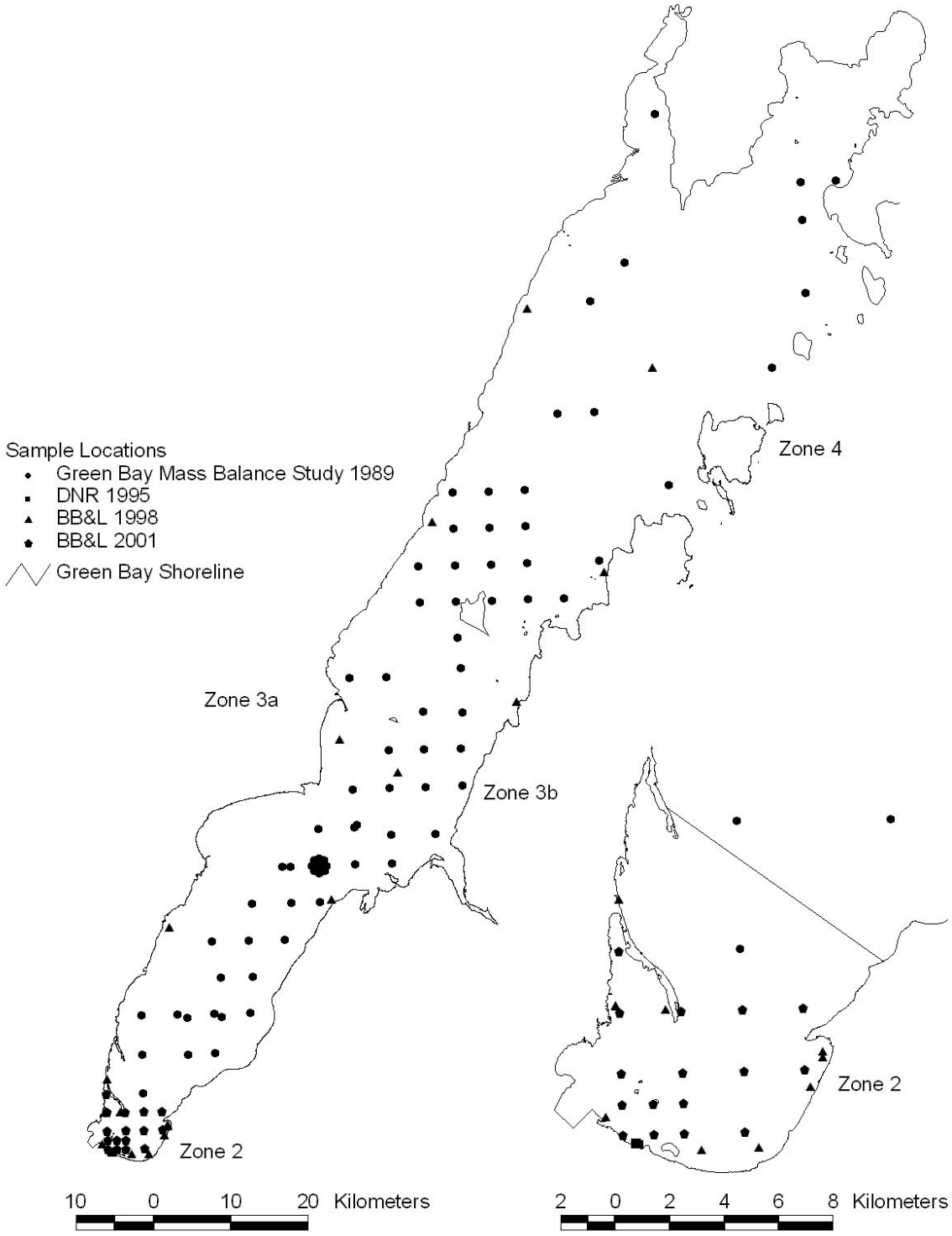
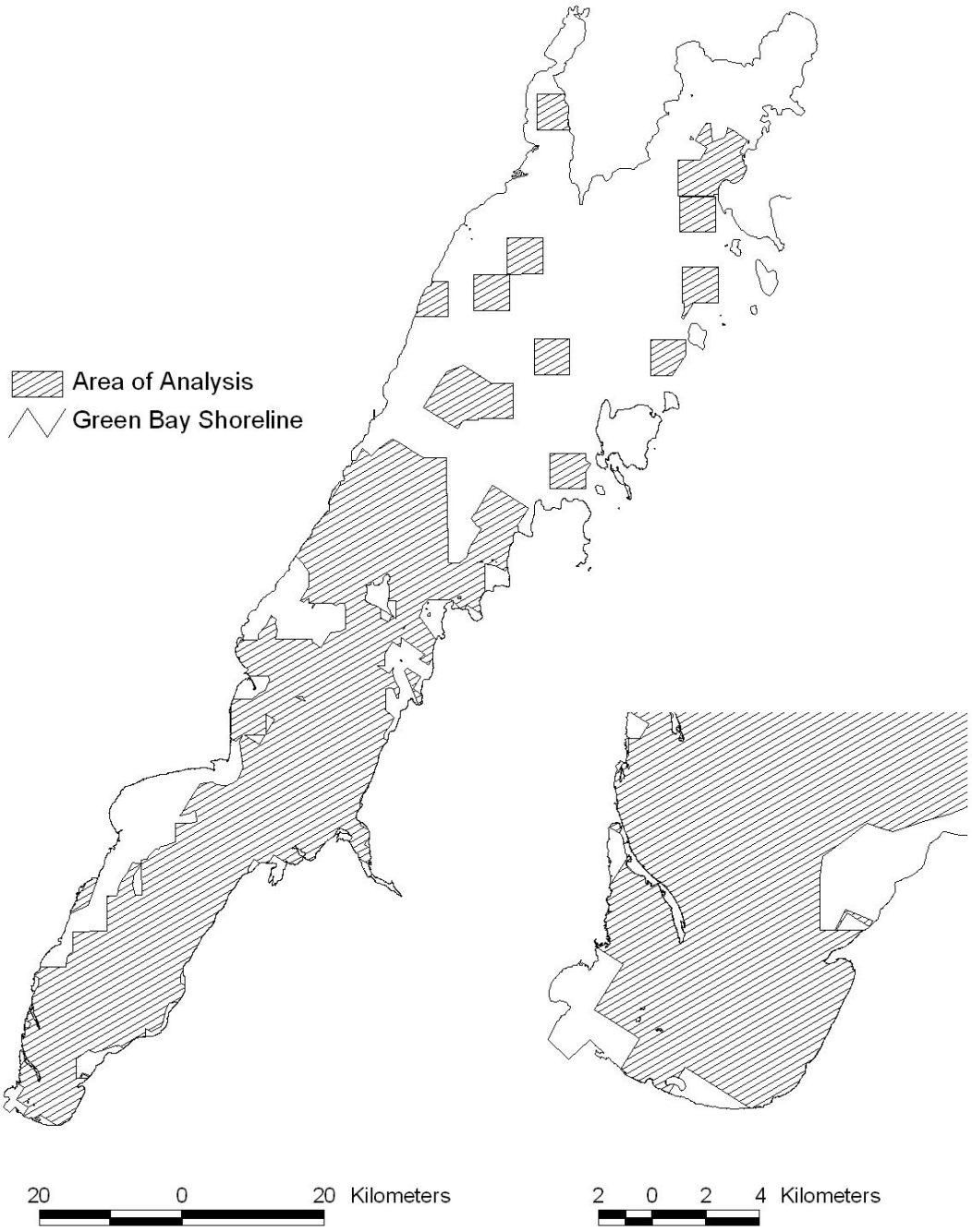


FIGURE 6 TM 2F ALTERNATIVE APPROACH AREA OF ANALYSIS COVERAGE



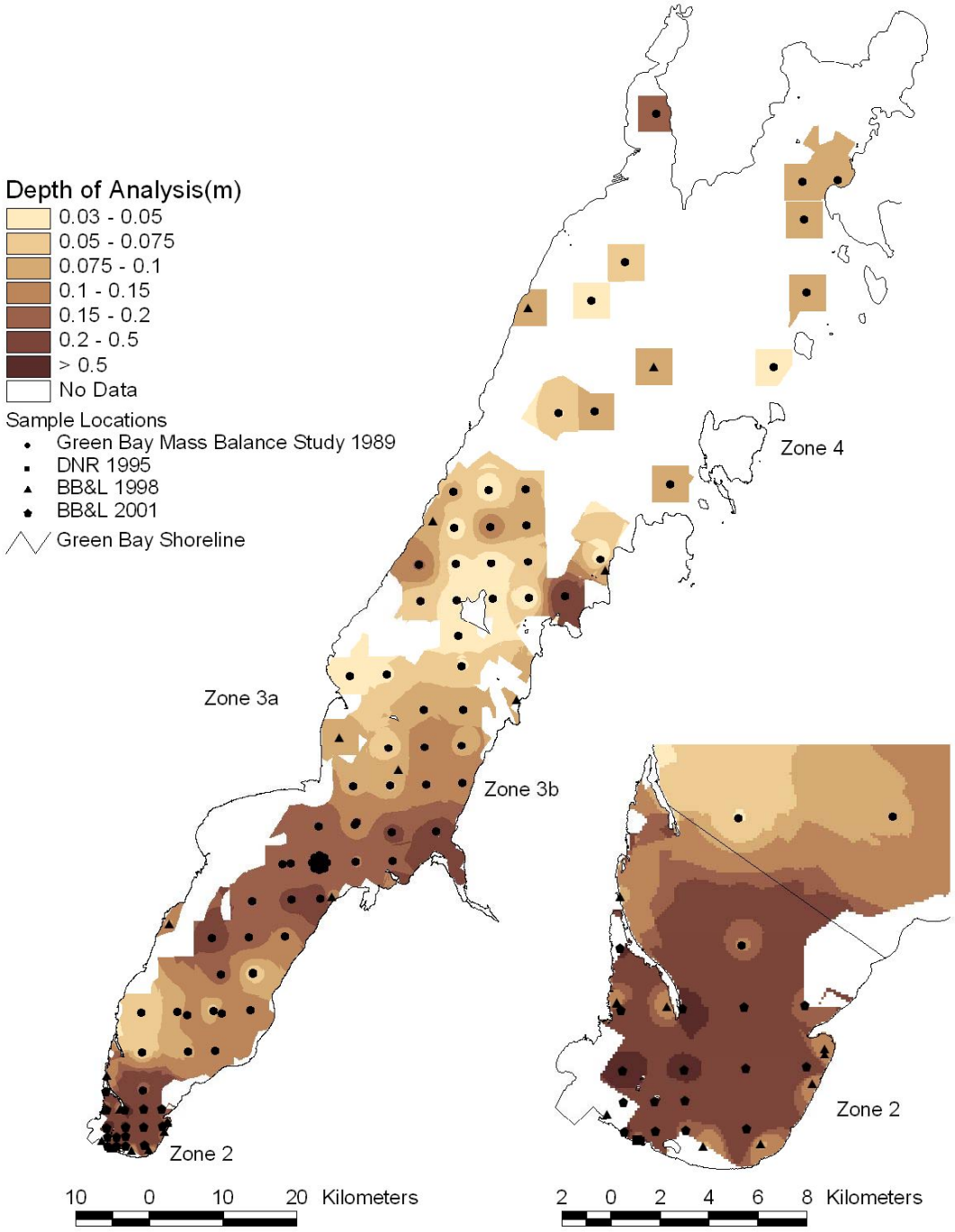
4.1.3 Depth of Analysis

In computations of mass and volume estimates, the depth of sediment can be a significant factor. The sediment profile depths used by UW to calculate thickness-weighted average mass estimates at each core location were defined by measured values for PCB concentrations. In TM 2f, the maximum depth at which bulk density measures were

observed defined the analysis depth at each sample location. In many cases, this was as deep as 30 cm or more. Because the measured bulk density values were often deeper in the sediment profile than accompanying or neighboring PCB concentration measures, "last known" PCB concentrations were assumed to extend to the bottom of the sediment profile. In TM 2f, a large volume of PCB-contaminated sediment was estimated to exist in the final layer of interpolation (Model Layer 5, greater than 10 cm).

For the alternative method, a new GIS coverage of Green Bay sediment depth-of-analysis was generated by using PCB sample results, rather than bulk density values, to define sample core depths (Figure 7). This approach to contaminated sediment depth is based on the assumption that PCBs detected at the bottom of core samples do not extend deeper into underlying un-sampled sediments.

FIGURE 7 TM 2F DEPTH OF ANALYSIS GIS GRID COVERAGE



4.2 RESULTS OF ALTERNATIVE ANALYSIS

Figure 8 is a map of Green Bay depicting the interpolated results of PCB concentrations in the top layer (0 to 2 cm) of sediment. It is important to note that, compared to the PCB concentration maps presented in TM 2f (Figure 5-7), the revised concentration estimates differ only slightly overall. In the north Bay (zones 3A, 3B, and 4), concentration

patterns and magnitudes remain essentially the same, while in the south Bay (Zone 2) there is a reduction in the concentration pattern. This difference is due to a bounding affect on the interpolation caused by the shallow, low-concentration PCB data collected by BBL in conjunction with the modified distance-weighting factor of the south-Bay IDW model.

Table 3 is a summary of PCB mass estimates and approximate surface concentrations-by-method for all of Green Bay. The surface concentrations are based on the 0- to 2-cm depth and are essentially the same. Differences in these mass estimates are due to minimizing the depth-of-analysis interpolation parameter and interpolating on sample-specific PCB mass, rather than multiplying resultant interpolations of PCB concentration and sediment bulk density. In the south Bay, mass differences are apparent in all sediment layers, due to the IDW model changes and the bounding-affect of the BBL PCB data. Throughout the remainder of the Bay, minor differences in PCB mass exist as a result of excluding "stand-alone" bulk density data points from the analysis.

FIGURE 8 TM 2F ALTERNATIVE APPROACH; PCB SURFACE CONCENTRATIONS (0 TO 2 CM)

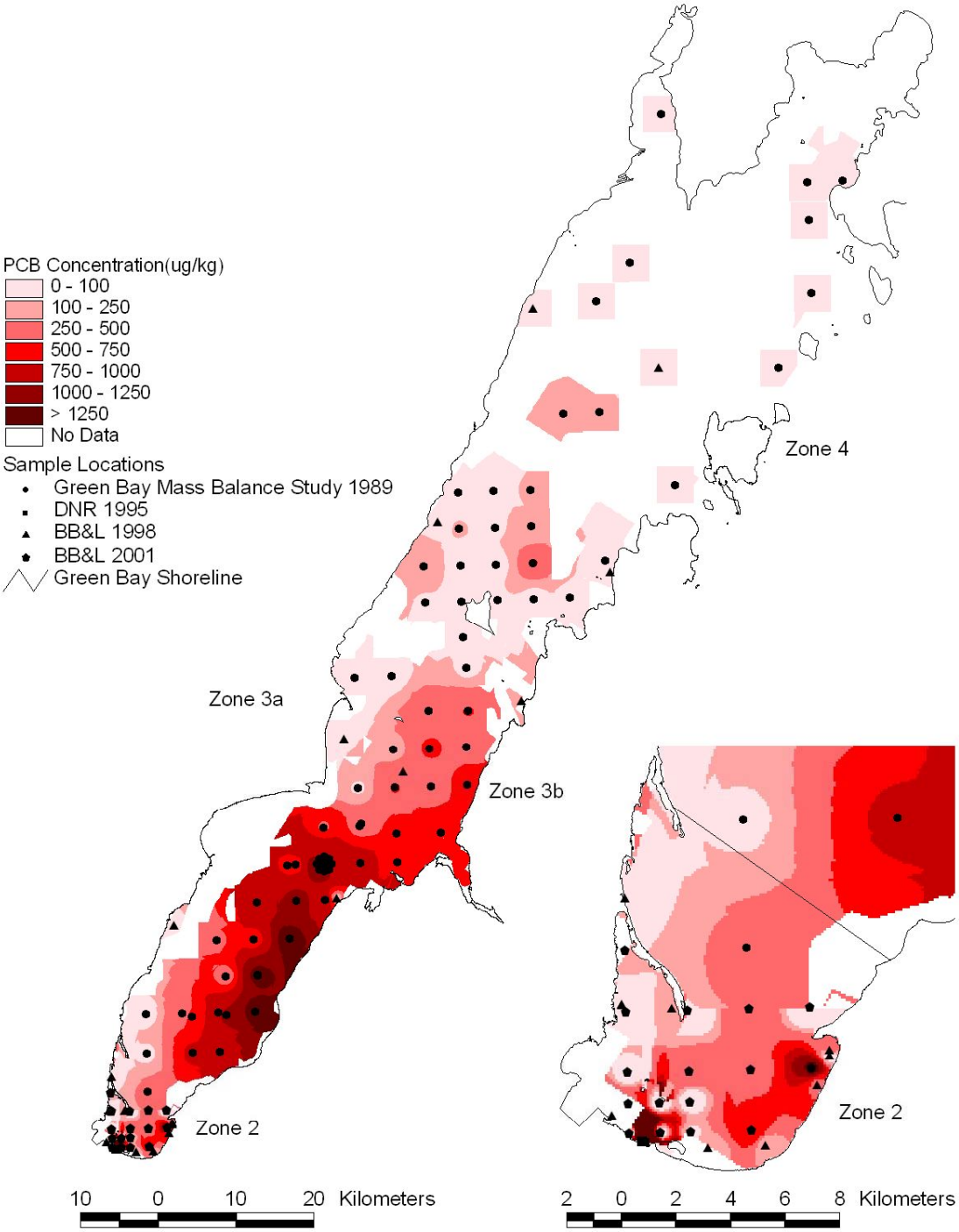


TABLE 3 GREEN BAY PCB MASS ESTIMATES (KG) AND SURFACE CONCENTRATIONS BY SOURCE AND METHODOLOGY

Source	PCB Mass Estimate (kg)	PCB Surface Concentration (ppm)
UW GBMBS	8,483	0.388
WDNR TM 2f	69,955	0.351
WDNR Alternative Method	14,603	0.353

4.2.1 Comparison of PCB Mass and Contaminated Sediment Volume

Table 4 is a summary of PCB mass estimate-by-sediment layer for each of the four zones in Green Bay using the alternative method. By comparing these results to the results in Table 5 (generated from TM 2f, Table B-4), 76 percent of the PCB mass difference is attributable to the large differences in sediment column fifth layer (greater than 10 cm). These differences are due primarily to minimizing the depth of analysis interpolation parameter and interpolating on "at core" PCB mass.

TABLE 4 GREEN BAY PCB MASS ESTIMATES (KG) BY SEDIMENT LAYER BAY ZONE USING ALTERNATIVE METHOD

Sediment Layer	Zone 2	Zone 3A	Zone 3B	Zone 4	Total
0–2 cm	351	582	929	307	**2,170**
2–4 cm	342	671	1,255	260	**2,528**
4–6 cm	393	761	1,218	261	**2,633**
6–10 cm	741	976	1,656	295	**3,668**
>10 cm	2,504	437	638	26	**3,605**
Total	**4,331**	**3,427**	**5,696**	**1,150**	**14,603**

TABLE 5 GREEN BAY PCB MASS ESTIMATES (KG) BY SEDIMENT LAYER BAY ZONE USING TM 2F (GENERATED FROM TM 2F, TABLE B-4)

Sediment Layer	Zone 2	Zone 3A	Zone 3B	Zone 4	Total
0–2 cm	1,471	1,746	1,709	390	**5,316**
2–4 cm	1,442	1,601	1,372	286	**4,701**
4–6 cm	1,442	1,601	1,372	286	**4,701**
6–10 cm	2,884	3,202	2,744	572	**9,402**
>10 cm	24,810	9,485	11,120	420	**45,835**
Total	**32,049**	**17,635**	**18,317**	**1,954**	**69,955**

Table 6 is a summary of PCB-contaminated sediment volume and mass estimates for each zone in Green Bay using the alternative method. Compared to results displayed in Table 7 (generated from TM 2f, Table B-5), there is nearly a 380,000,000 cubic meter difference in the estimates of total contaminated sediment volume. This difference is evident in all zones and appears to be primarily due to minimizing the depth of analysis across the whole Bay.

TABLE 6 PCB-CONTAMINATED SEDIMENT VOLUME AND MASS BY ZONE USING ALTERNATIVE METHOD

Bay Zone	Volume of Contaminated Sediment (m^3)	% Total Volume	PCB Inventory (kg)	% Total PCB Inventory
2	28,710,478	12	4,331	30
3A	64,487,652	27	3,427	23
3B	83,151,447	34	5,696	39
4	66,193,726	27	1,150	8
Total	**242,543,303**	**100**	**14,603**	**100**

TABLE 7 PCB-CONTAMINATED SEDIMENT VOLUME AND MASS BY ZONE USING TM 2F (GENERATED FROM TM 2F, TABLE B-5)

Bay Zone	Volume of Contaminated Sediment (m^3)	% Total Volume	PCB Inventory (kg)	% Total PCB Inventory
Zone 2	39,582,000	6	32,049	46
Zone 3A	244,617,000	39	17,635	25
Zone 3B	191,629,000	31	18,317	26
Zone 4	146,525,000	24	1,954	3
Total	**622,353,000**	**100**	**69,955**	**100**

4.2.2 Comparison of PCB Surface Concentrations

Table 8 is based on Figure 8 and provides a comparison of PCB surface concentrations in the top layer (0 to 2 cm) of sediment using the TM 2f approach and the alternative method. The revised concentration estimates in the north Bay (zones 3A, 3B, and 4) have similar magnitudes and remain essentially the same using the alternative method while in the south Bay (Zone 2) there is a reduction in the concentration. This difference in Zone 2 is due to a bounding affect on the interpolation caused by the shallow and low-concentration PCB data in the south Bay.

TABLE 8 PCB SURFACE CONCENTRATIONS BY ZONE AND MODEL SEGMENT IN THE 0- TO 2-CM PROFILE

Bay Zone	TM 2f (µg/kg)	Alternative Method (µg/kg)	Model Segment	TM 2f (µg/kg)	Alternative Method (µg/kg)
2	0.76	0.32	1	2,010	418
			2	273	182
			3	674	377
3A	0.34	0.37	4	274	347
			5	609	741
			8	531	625
3B	0.57	0.69	6	776	1,060
			7	359	382
4	0.1	0.08	9	92	82

5 CONCLUSIONS

Given the expansiveness of the Bay, reliable sediment data is still sparse in many areas and there is some uncertainty associated with any method of estimating existing PCB mass and contaminated sediment volume in the Bay. As presented in both TM 2f and the UW method, it is possible to develop a variety of PCB mass estimates for Green Bay. This alternative method developed as part of this evaluation provides a sound estimate of PCB mass in Green Bay. The following conclusions can be reached:

- When parameters such as data, areal coverage, and depth are equalized, the methods used by the UW and in TM 2f have similar results. Both the TM 2f method and the UW method in the GBMBS are legitimate techniques for estimating PCB mass, contaminated sediment volumes, and PCB surface concentrations in Green Bay.

- The UW mass and volume estimates are low because the estimates do not include any data south of Long Tail Point. Consequently, based on receipt of new information presented in this white paper from that area allows for a mass and volume estimate for that area.

- There is a large scientifically valid data set for Green Bay. Since this data is not made up completely of matching PCB concentration and bulk density values, it can not all be used in the alternative method. This data provides for information on varying PCB concentration values, differing depths, ranges of bulk density, etc. Selection of input data plays a significant role in PCB mass and contaminated sediment volume estimates of the techniques selected.

- Sediment depth and bulk density values can greatly impact PCB mass and contaminated sediment volume estimates.

- In addition to bulk density and PCB concentration, other parameters such as depth of analysis and extent of coverage also factor into PCB mass and contaminated sediment estimates.

- Regardless of method used, the PCB surface concentration for the zones in Green Bay are similar.

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APPENDIX A

CD DIRECTORY LIST AND DATA CD

CD DIRECTORY LIST

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